

Extragalactic dark matter and direct detection experiments

A. N. Baushev*

DESY, 15738 Zeuthen, Germany

Institut für Physik und Astronomie, Universität Potsdam, 14476 Potsdam-Golm, Germany

ABSTRACT

Recent astronomical data strongly suggest that a significant part of the dark matter, composing the Local Group and Virgo Supercluster, is not incorporated into the galaxy haloes and forms diffuse components of these galaxy clusters. Apparently, a portion of the particles from these components may penetrate into the Milky Way and make an extragalactic contribution to the total dark matter containment of our Galaxy.

We find that the particles of the diffuse component of the Local Group are apt to contribute $\sim 12\%$ to the total dark matter density near the Earth. The particles of the extragalactic dark matter stand out because of their high speed (~ 600 km/s), i.e. they are much faster than the galactic dark matter. In addition, their speed distribution is very narrow (~ 20 km/s). The particles have isotropic velocity distribution (perhaps, in contrast to the galactic dark matter). The extragalactic dark matter should give a significant contribution to the direct detection signal. If the detector is sensitive only to the fast particles ($v < 450$ km/s), the signal may even dominate.

The density of other possible types of the extragalactic dark matter (for instance, of the diffuse component of the Virgo Supercluster) should be relatively small and comparable with the average dark matter density of the Universe. However, these particles can generate anomaly high energy collisions in direct dark matter detectors.

Key words: dark matter, elementary particles, galaxies: haloes, solar neighbourhood.

1 INTRODUCTION

It is widely believed that all the dark matter particles (hereafter DMPs), which a terrestrial observer can detect, belong to the Milky Way Galaxy. The main aim of this letter is to dispute this assertion and to show that a remarkable fraction of dark matter particles detected on the Earth does not probably belong to our Galaxy. Although their density is relatively small, as compared with the total dark matter density, their impact into the direct detection signal may even dominate because of high speeds of the particles.

According to the modern cosmological notion, the haloes of giant galaxies, like Milky Way or Andromeda, are regions of local dark matter overdensity, rather than isolated islands. Indeed, the Local Group, along with the haloes of large and dwarf galaxies, contains a significant fraction of dark matter that is not bound in the galaxies and presumably forms a large envelope of the Local Group (Binney & Tremaine 2008). A significant part of the dark matter of the Virgo Supercluster is also not localized in haloes and probably distributed more or less

homogeneously over all the volume of the Supercluster (Makarov & Karachentsev 2011). Some part of this diffuse dark matter (preeminently from the Local Group envelope) penetrates into the central region of our Galaxy and gives a contribution to the direct detection signal, which can even dominate under certain conditions: as we will see, the density fraction of the extragalactic dark matter is relatively small ($\sim 12\%$), however its particles should have extremely high speeds, close to the escape velocity (~ 600 km/s) or even higher. It sets off the extragalactic particles from the halo DMPs with much lower average speed. The direct detection signal produced by this component should also have some other characteristic features that will be discussed below.

2 THE DARK MATTER ENVELOPE OF THE LOCAL GROUP

Unfortunately, the total mass, distribution and dynamical properties of the extragalactic dark matter environment are now poorly known. Therefore, we have to do with rough estimates of its content near the Solar System.

* E-mail: baushev@gmail.com

The Local Group consists of two very massive galaxies (Milky Way and Andromeda galaxy M31), less massive Triangulum galaxy M33, and a host of dwarf galaxies. It seems reasonable to say that the Local Group contains a massive diffused dark matter component as well (Kahn & Woltjer 1959). Unfortunately, some parameters of the system have not been measured with the adequate accuracy. We accept the following values in this letter: the radius of the Solar System orbit $l_\odot = 8$ kpc, the Milky Way mass $M_{MW} = 10^{12} M_\odot$, the Andromeda galaxy mass $M_{31} = 1.6 \times 10^{12} M_\odot$, the distance between them $d = 750$ kpc (Cox & Loeb 2008). The tangential components of the velocities of even some massive members of the Local Group are also not quite explored, and we know almost nothing about the distribution and dynamical parameters of the diffused component: so the investigation of its motion in the complex gravitational field of several bodies is quite a difficult and underdefined task. However, our aim is much simpler: we would like to model just the process of the envelope dark matter penetration towards the Solar System. Taking into account all the above-mentioned uncertainties, we will try to construct a simple toy model, that does not claim to describe all properties of the Local Group, allowing us, however, to estimate the density and the velocity distribution of the extragalactic dark matter near the Solar System.

Let us consider the following model: the system is stationary and spherically-symmetric. Specific angular momentum $\mu \equiv [\vec{v} \times \vec{r}]$ and maximum radius r_0 the particle moves from the centre remain constant for each particle in such a system, and gravitational potential $\phi(r)$ depends only on r . r_0 of the particles belonging to the envelope lie in some interval $[r_{in}, r_{out}]$. We accept $r_{in} = 300$ kpc, which approximately corresponds to the size of the Milky Way Roche lobe in system Milky Way - M31, $r_{out} = 600$ kpc, in accordance with (Cox & Loeb 2008). The particles have some distribution $f(r_0)$ over r_0 inside $[r_{in}, r_{out}]$; we assume that their specific angular momentum $\mu \equiv [\vec{v} \times \vec{r}]$ has Gaussian distribution. So the overall distribution (i.e. the mass dm of particles in some interval $dr_0 d\mu$) is:

$$dm = f(r_0) \frac{2\mu}{\alpha^2} \exp\left(-\frac{\mu^2}{\alpha^2}\right) d\mu dr_0, \quad r_0 \in [r_{in}, r_{out}] \quad (1)$$

where α is, generally speaking, a function of r_0 . We accept the envelope mass $M_{env} = \int_{r_{in}}^{r_{out}} f(r_0) dr_0 = 10^{12} M_\odot$. This value is noticeably smaller than the total mass of the diffused component, which is estimated as $\sim M_{MW} + M_{31} = 2.6 \times 10^{12} M_\odot$ (Cox & Loeb 2008). We allow for, however, that the main part of this substance surrounds and accretes on the Andromeda galaxy, and take only $M_{MW}/(M_{MW} + M_{31})$ of the total mass, so we assume that the mass should be divided proportionally to the Roche lobe areas of the components.

At first glance it would seem that the above-stated model is completely unusable to describe the dark matter motion in the Local Group: the gravitational field of the system by no means can be considered as central on the scale ~ 600 kpc, because of huge perturbations from other group members, especially from the Andromeda galaxy. However, we are only interested in the envelope dark matter penetration towards the Solar System, and this process is totally defined by the angular momenta of the particles: only the particles with very small momenta can reach the Earth. The motion of the particles near the Solar System is almost

unaffected by M31 ($l_\odot \ll d$) and may well be described by the above-mentioned model. When a particle moves from the envelope to the Earth, its angular momentum is, of course, strongly influenced by the tidal perturbations. However, we almost do not know the momentum distribution of the particles in the envelope. Therefore equation (1) may be thought of as describing the resultant distribution of the falling particles with regard to the perturbations from the other members of the Local Group. Moreover, as we will see, the shape of angular momentum distribution is not very important: we actually use only the value at $\mu = 0$. As for perturbations of the particle energy, they are of the order of GM_{31}/d , i.e. always small. This is a result of the fact that the main part of the particle acceleration takes place deep in the Milky Way, where the gravitational field is much stronger.

Now we should find the particle distribution inside radius r_{in} . A very similar task has been studied extensively in (Baushev 2012a). We cite here only the results adaptable to our work, skipping the complete derivation. The exact distribution inside r_{in} depends on r and is equal to:

$$\rho = \int_{r_{in}}^{r_{out}} \int_0^{\mu_{max}} \frac{f(r_0) r_0 \mu \exp(-\mu^2/\alpha^2) d\mu dr_0}{2\pi r \alpha^2(r_0) T(r_0, \mu) \sqrt{r_0^2 - r^2} \sqrt{\mu_{max}^2 - \mu^2}} \quad (2)$$

Here $T(r_0, \mu)$ is the half-period of a particle with maximal radius r_0 and specific angular momentum μ , i.e. the time it takes for the particle to fall from its maximal radius to the minimal one, and μ_{max} is the maximum angular momentum of a particle wherewith it can reach radius r

$$\mu_{max}^2 = 2(\phi(r_0) - \phi(r)) \left(\frac{1}{r^2} - \frac{1}{r_0^2} \right)^{-1} \quad (3)$$

Our concern is only with the particle distribution at $r = l_\odot$. Since $l_\odot \ll r_{in} < r_0$, we can simplify the above equations

$$\rho = \int_{r_{in}}^{r_{out}} \int_0^{\mu_{max}} \frac{f(r_0) \mu \exp(-\mu^2/\alpha^2) d\mu dr_0}{2\pi l_\odot \alpha^2(r_0) T(r_0) \sqrt{\mu_{max}^2 - \mu^2}} \quad (4)$$

$$\mu_{max}(l_\odot) = l_\odot \sqrt{2(\phi(r_0) - \phi(l_\odot))} \quad (5)$$

Here we took into account that for $\mu \in [0, \mu_{max}(l_\odot)]$ period $T(r_0, \mu)$ is almost independent on μ ($T(r_0, \mu) \simeq T(r_0, 0) \equiv T(r_0)$), see (Baushev 2012a) for details.

Equation (4) can be significantly simplified, if we take into account that $\alpha(r_0)$ is physically constrained. On the one hand, $\alpha(r_{out})$ hardly can be higher, than

$$\alpha(r_{out}) = \frac{1}{3} r_{out} \sqrt{\frac{2G(M_{MW} + M_{env})}{r_{out}}} \quad (6)$$

since in the opposite case a significant fraction of the particles would have the speed above the escape velocity at this radius. On the other hand, numerical simulations (Stadel et al. 2009) show that the root-mean-square angular momentum of the particles should be quite high and close to upper limit (6). Though there is rather strong evidence that α of the particles of our Galaxy is much lower (Baushev 2011), we will use value (6) in our calculations, since the density of the extragalactic dark matter grows with decreasing of α , and we take the maximum possible value in order to obtain a conservative estimate. The dependence of α on r_0

is not well known, and we will presume it to be power-law

$$\alpha(r_0) = \alpha(r_{out}) \left(\frac{r_0}{r_{out}} \right)^i \quad (7)$$

However, we only need much softer condition $\alpha(r_0) \geq \mu_{max}(l_\odot)$ to simplify (4). It means that the tangential velocity dispersion in the envelope is supposed to be higher than $v_{esc} \frac{l_\odot}{r_{in}} \simeq 16$ km/s. Such an assumption seems quite natural. If $\alpha(r_0) \geq \mu_{max}(l_\odot)$, we can simplify (4) as

$$\rho = \frac{\int_{r_{in}}^{r_{out}} \int_0^{\mu_{max}} \frac{f(r_0) \mu d\mu dr_0}{2\pi l_\odot \alpha^2(r_0) T(r_0) \sqrt{\mu_{max}^2 - \mu^2}} \quad (8)$$

Now we should ascertain the velocity distribution of the particles. Let us denote the tangential and radial components, and the total velocity of a particle at $r = l_\odot$ by u_τ , u_r , and u respectively. We can use u_τ and u instead of r_0 , μ . Indeed, $\mu = u_\tau l_\odot$, $u = \sqrt{2(\phi(r_0) - \phi(l_\odot))}$, $\mu_{max} = ul_\odot$. Let us consider the particles with the same u (i.e., with the same r_0) and find their angular distribution. An element $d\Omega$ of the solid angle in the phase space is equal to

$$d\Omega = \frac{u}{u_r} \frac{2\pi u_\tau du_\tau}{4\pi u^2} = \frac{\mu d\mu}{2l_\odot \sqrt{\mu_{max}^2 - \mu^2} \sqrt{2(\phi(r_0) - \phi(l_\odot))}} \quad (9)$$

Substituting this equation to (8), we obtain

$$\rho = \int_{r_{in}}^{r_{out}} \frac{f(r_0) \sqrt{2(\phi(r_0) - \phi(l_\odot))} dr_0}{\pi \alpha^2(r_0) T(r_0)} \int d\Omega \quad (10)$$

As we can see, the particle distribution depends only on r_0 (i.e., on velocity magnitude u), and is independent on the direction. So the distribution is isotropic. u and r_0 are bound by a one-to-one relation

$$u = \sqrt{2(\phi(r_0) - \phi(l_\odot))} \quad du = \frac{\left(\frac{d\phi(r_0)}{dr_0} \right) dr_0}{\sqrt{2(\phi(r_0) - \phi(l_\odot))}} \quad (11)$$

We can substitute this equation to (10) and take into account that $\int d\Omega = 4\pi$.

$$\rho = \frac{\int_{\sqrt{2(\phi(r_{out}) - \phi(l_\odot))}}^{\sqrt{2(\phi(r_{out}) - \phi(l_\odot))}} \frac{8f(r_0)(\phi(r_0) - \phi(l_\odot))}{\alpha^2(r_0) T(r_0) (d\phi(r_0)/dr_0)} du \quad (12)$$

Hence the velocity distribution of the dark matter from the envelope is isotropic near the Solar System; equations (11) and (12) totally define its density and momentum distribution.

In order to complete the solution, we should define functions $\phi(r_0)$, $T(r_0)$, and $f(r_0)$. We will assume $f(r_0)$ to be a power-law function with some index j . Since $\int f(r_0) dr_0 = M_{env}$,

$$f(r_0) = \frac{(j+1)M_{env}}{r_{out} - r_{in}} \left(\frac{r_0}{r_{out} - r_{in}} \right)^j \quad (13)$$

We accept the mass distribution at $r > r_{in}$ to be

$$M(r) \simeq M_{MW} + M_{env} \left(\frac{r - r_{in}}{r_{out} - r_{in}} \right)^{j+1} \quad (14)$$

This equation is not quite true, because in fact the particles

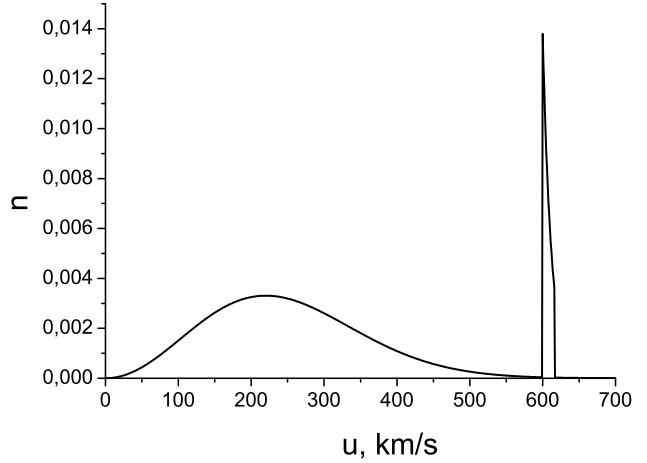


Figure 1. The normalized velocity distribution of dark matter particles near the Earth in the frame of reference that does not rotate around the Galaxy centre. The distribution of the galactic DMPs is supposed to be Maxwell (23). The extragalactic component gives a narrow high peak near 600 km/s.

contribute as well to the mass inside r_{in} . However, our calculation is estimative, and we may disregard rather a small deviations from (14). With the same accuracy $T(r_0)$ may be thought of as a power-law function. One can readily see that $T(r_0) \propto r^{1-\frac{j}{2}}$ if $M(r) \propto r^{j+1}$. Though the mass distribution is not quite power-law in our case, we presume

$$T(r_0) = T(r_{in}) \left(\frac{r_0}{r_{in}} \right)^{1-\frac{j}{2}} \quad (15)$$

and $T(r_{in}) = 10^{17}$ s, which is slightly more, than the time necessary for a body to fall on point mass $10^{12} M_\odot$ from 300 kpc with no initial velocity. Function $\frac{d\phi(r_0)}{dr_0} = \frac{GM(r_0)}{r_0^2}$ is totally defined by (11).

$$\frac{d\phi(r_0)}{dr_0} = \frac{G}{r_0^2} \left[M_{MW} + M_{env} \left(\frac{r_0 - r_{in}}{r_{out} - r_{in}} \right)^{j+1} \right] \quad (16)$$

As for function $\sqrt{2(\phi(r_0) - \phi(l_\odot))}$, it remains almost constant for $r_0 \in [r_{in}; r_{out}]$ owing to the smallness of $|\phi(r_{out}) - \phi(r_{in})|$ as compared with $|\phi(r_{in}) - \phi(l_\odot)|$. Therefore we can approximate $\sqrt{2(\phi(r_0) - \phi(l_\odot))} \simeq \sqrt{2(\phi(r_{in}) - \phi(l_\odot))} \equiv V$. Hereafter we accept $V = 600$ km/s. The velocities of all the particles lie in a very narrow interval ΔV

$$\Delta V = \sqrt{V^2 + 2(\phi(r_{out}) - \phi(r_{in}))} - V \quad (17)$$

Now we should substitute equations (7), (15), (13) for $\alpha(r_0)$, $T(r_0)$, $f(r_0)$ respectively and (6) for $\alpha(r_{out})$ into equation (12). It is convenient to introduce $k \equiv r_{out}/r_{in} = 2$. After some trivial calculations we obtain

$$\rho = 9 \frac{(j+1)}{(\frac{3}{2}j - 2i)} \frac{k^{2j}(k^{\frac{3}{2}j-2i} - 1)}{(k-1)^{j+1}} \frac{V}{GT(r_{in})r_{out}} \quad (18)$$

The shape of velocity distribution function n in the phase space is given by

$$n(u) \propto \frac{du^3}{4\pi u^2} r_0^{\frac{3}{2}j-2i-1} \left(\frac{dr_0}{du} \right) \quad (19)$$

where we should substitute r_0 by $u \in [V, V + \Delta V]$ with the help of equations (13) and (16). Equations (18), (19) completely determine the solution of the task.

3 RESULTS AND DISCUSSION

Not much is known about the dark matter distribution in the envelope. On the other hand, as we can see from equation (18), the result is not strongly dependent on the choice of i and j (as a consequence of the relative smallness of ratio r_{out}/r_{in}). It seems reasonable to choose i and j by analogy with the well-known isothermal halo solution ($dM/dr = \text{const}$ and the Maxwell DMP velocity distribution with a temperature, constant over the halo), which corresponds to $i = 1$, $j = 0$. Substituting these values in combination with $T(r_{in})$, $\alpha(r_{in})$, and V to (18), we obtain the density of the extragalactic dark matter near the Earth $\rho = 3.7 \times 10^{-2} \text{ GeV/cm}^3$. The speed distribution is notably narrow: the absolute values of all particles fall within $\Delta V \simeq 16 \text{ km/s}$. As we have already mentioned, this feature is a consequence of the smallness of $|\phi(r_{out}) - \phi(r_{in})|$ as compared with $-\phi(l_\odot)$. Therefore, two properties of the velocity distribution are model-independent: the speeds of extragalactic DMPs from the envelope lie in a narrow range, and their angular distribution is isotropic.

The density of the extragalactic dark matter turns out to be fairly high: $3.7 \times 10^{-2} \text{ GeV/cm}^3$ is more than 12% of the total dark matter density near the Earth $\simeq 0.3 \text{ GeV/cm}^3$ (Gorbunov & Rubakov 2011). This brings up a question: How reliable is the estimation? Above we have already discussed the approximation of the system by a spherically symmetric model and found it acceptable. The premise that $f(r_0)$ terminates abruptly at r_{in} and r_{out} is also unphysical. Undoubtedly, our result is assessed; however, it cannot be called optimistic. Indeed, as the dimensional method shows, for any envelope model the density of the extragalactic dark matter is, with an accuracy of a numerical factor, equal to

$$\rho \propto \frac{M_{env} v_{esc}}{\langle \alpha \rangle^2 \langle T \rangle} \quad (20)$$

where $\langle \alpha \rangle$ and $\langle T \rangle$ are the average values of the respective quantities. Our calculations confirm this dependence: it can be easily obtained from (12). v_{esc} is almost independent on the model choice. $\langle T \rangle$ is essentially defined by the size of the Milky Way Roche lobe, and thus is also more or less model-independent. The main source of the uncertainty is envelope mass M_{env} . We proceed from the assumption of Cox & Loeb (2008) that M_{env} is approximately equal to the masses of the galaxies of the Local Group. We used the highest possible value (6) for α : if α was higher, a significant part of the envelope would rapidly evaporate. Since $\rho \propto \alpha^{-2}$, this choice is conservative.

Thus there are two possible situations, when (18) significantly overestimates the density of the extragalactic dark matter. It may be so, if the envelope mass is in fact much lower than the masses of the Local Group member galaxies. The strong overestimation may also appear, if the angular momentum distribution of the envelope DMPs differs greatly from the Gaussian (1), i.e., almost all the particles have circular orbits. Such a supposition seems highly improbable. First of all, it is in sharp contrast to N-body simulation results (Stadel et al. 2009). There is also a good indirect counterargument: the largest Local Group member M31 has quite low angular momentum and, consequently, very oblong orbit (Kahn & Woltjer 1959). It is plausible that Milky Way and M31 will finally experience a central collision. Thus the presence in the diffuse component of the Local Group of a

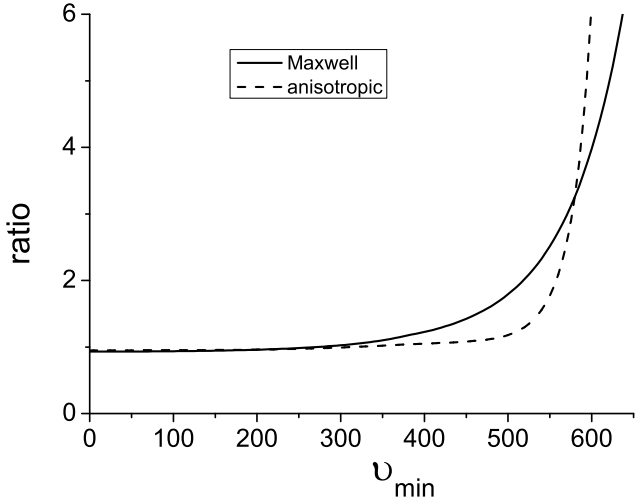


Figure 2. The ratio of the direct detection signal produced by the mixture $\sim 12.3\%$ of extragalactic component and 87.7% of the galactic DMPs to the signal produced by pure galactic dark matter. The fraction and velocity distribution of the extragalactic component were calculated in accordance with (18). We considered two models of the velocity distribution of the galactic DMPs: Maxwell (23) (solid line) and anisotropic (24) (dashed line). The extragalactic dark matter almost does not affect the signal, if $v_{min} < 300 \text{ km/s}$, but totally dominates above $450 - 500 \text{ km/s}$.

bulk of dark matter particles that have very oblong orbits and can reach the Earth seems quite possible.

The 12% extragalactic component of the total dark matter density can be especially important for the direct dark matter search. The direct search is based on the detection of the collisions of dark matter particles with nuclei of the target. The signal is sensitive to the velocity distribution: roughly speaking Bélanger, Nezri, & Pukhov (2009), it is proportional to

$$I(v_{min}) = \int_{v_{min}}^{\infty} \frac{\tilde{n}(v)}{v} d^3\vec{v} \quad (21)$$

Here $\tilde{n}(v)$ is the distribution in the Earth's frame of reference: it should be obtained from (19), (23), or (24) by a Galilean transformation. v_{min} is the minimal DMP speed, to which the detector is sensitive (see details in Bélanger, Nezri, & Pukhov (2009)).

$$v_{min}^2 \simeq \frac{E_A (m_\chi + m_A)^2}{2 m_A m_\chi^2} \quad (22)$$

where m_χ and m_A are the DMP and the detector nucleus mass respectively, E_A is the detector activation energy, depending on its construction. In order to estimate the influence of the extragalactic dark matter to the direct detection signal, we should define a model for the velocity distribution of the galactic component. The Maxwell distribution is now routinely used, mainly because of its simplicity:

$$n(u) = \frac{1}{(\sqrt{\pi} v_\odot)^3} \exp\left(-\frac{u^2}{v_\odot^2}\right) \quad (23)$$

v_\odot is the orbital speed of the Solar System. There are strong reasons to suppose, however, that the distribution of the

galactic DMPs is strongly anisotropic and looks like

$$n(u) = \frac{\exp\left(-\frac{u_r^2}{2\sigma_0^2}\right)}{2\pi^2\sigma_0^2\sqrt{u_{max}^2 - u_r^2}} \quad (24)$$

where $u_r \in [-v_{max}; v_{max}]$, $u_{max} \simeq 560$ km/s, $\sigma_0 = 80$ km/s, u_r and u_τ are radial and tangential components of the particle velocity, respectively (Baushev 2011).

We calculated the signal produced by mixture of 3.7×10^{-2} GeV/cm³ of the extragalactic dark matter and 0.263 GeV/cm³ of the galactic one and divided it by the signal produced by the pure galactic dark matter with the same total density (0.3 GeV/cm³). We used both models of the galactic DMP distribution: Maxwell (23) and anisotropic (24). The two ratios are represented in Fig. 2 by the solid line (Maxwell velocity distribution of the galactic dark matter particles) and by the dashed line (anisotropic velocity distribution). One can see that the signal is scarcely affected by the presence of the extragalactic component, if $v_{max} < 300$ km/s. However, the situation drastically changes for higher v_{max} ; if v_{max} is larger, than 450–500 km/s, the extragalactic signal dominates. This is not particularly surprising: all the extragalactic particles are faster than 600 km/s, while the number of the galactic particles rapidly drops above ~ 450 km/s. Hence the impact of the extragalactic dark matter to the direct detection signal can be very important, especially if the DMP mass m_χ is small. Indeed, if m_χ is small, v_{max} is high (22), i.e., we can detect only the fastest DMPs. For instance, DAMA collaboration reports (Bernabei et al. 2011) about the detection of a signal produced by ~ 10 GeV weakly interacting massive particles. We shall not discuss here the question of the nature of the signal (other detectors do not confirm the result (Aprile et al. 2011)). It should be recorded, however, that $v_{max} > 450$ km/s for the majority of detectors, if the DMP is so light, i.e., the extragalactic component signal should totally dominate.

Notice that we should, strictly speaking, have cut distributions (23) and (24) at $u = v_{esc}$. However, the fraction of the particles with $u > v_{esc}$ is negligible for both the distributions, and the cutting would hardly affect the result; the impact of the extragalactic component would be even slightly higher.

In conclusion, let us briefly consider the extragalactic dark matter that does not belong to the Local Group. As recent astronomical observations imply (Makarov & Karachentsev 2011), the dark matter of the Virgo Supercluster, in addition to galaxies and their groups, forms a large diffuse component. We do not know its velocity and space distributions, but it seems reasonable to assume that the dark matter is distributed more or less uniformly, and the velocity dispersion of the DMPs is comparable with that of the observable members of the Supercluster ($v_\infty \sim 500$ km/s). The measurements estimate the average density of the diffuse component as $\rho \sim 10^{-6}$ GeV/cm³. The gravitational field of the Local Group should increase this quantity near the Earth. However, we can roughly estimate the enhancement as $1 + v_{esc}^2/v_\infty^2$, where $v_{esc} \simeq 650$ km/s is the escape velocity from the Solar System orbit (Baushev 2012b). Thus the density of the Supercluster dark matter is approximately 3 times higher near the Solar System, but yet hardly exceeds 10^{-5} GeV/cm³. This value is so low, that it may scarcely be of interest for modern experiments.

On the other hand, the Supercluster DMPs are particularly energetic ($v > 1000$ km/s) and hence may give a very characteristic signal.

To summarize:

1) The particles of the diffuse component of the Local Group are apt to contribute $\gtrsim 10\%$ to the total dark matter density near the Earth.

2) The particle speeds are ~ 600 km/s, i.e. they are much faster than the galactic DMPs. The particles have isotropic velocity distribution (perhaps, in contrast to the galactic dark matter); their speed distribution is very narrow ($\Delta V \sim 20$ km/s).

3) The extragalactic dark matter should give a significant contribution to the direct detection signal. If the detector is sensitive only to the fast particles ($v > 450$ km/s), the signal may even dominate.

4) The density of other types of the extragalactic dark matter (for instance, of the DMPs forming the diffuse component of the Virgo Supercluster) should be relatively small and comparable with the average dark matter density of the Universe. However, these particles can generate anomaly high-energy collisions in direct dark matter detectors.

Financial support by Bundesministerium für Bildung und Forschung through DESY-PT, grant 05A11IPA, is gratefully acknowledged. BMBF assumes no responsibility for the contents of this publication.

REFERENCES

- Aprile E. et al., [XENON100 Collaboration], 2011, Phys. Rev. Letters, 107, 131302 arXiv:1104.2549
- Baushev A. N., 2011, MNRAS, 417, L83
- Baushev A. N., 2012a, arXiv, arXiv:1205.4302
- Baushev A. N., 2012b, MNRAS, 420, 590
- Bélanger G., Nezri E., Pukhov A., 2009, PhRvD, 79, 015008
- Bernabei R., et al., 2011, AIPC, 1417, 12
- Binney J., Tremaine S., 2008, Galactic Dynamics: Second Edition, ISBN 978-0-691-13026-2 (HB), Princeton University Press, Princeton, NJ USA, 2008.
- Cox T. J., Loeb A., 2008, MNRAS, 386, 461
- Gorbunov, D. S., and Rubakov, V. A., 2011, vol. 1, *Hot Big Bang theory*, World Scientific, Singapore.
- Gorbunov, D. S., and Rubakov, V. A., 2011, vol. 2, *Cosmological perturbations and inflationary theory*, World Scientific, Singapore.
- Kahn F. D., Woltjer L., 1959, ApJ, 130, 705
- Makarov D., Karachentsev I., 2011, MNRAS, 412, 2498
- Stadel J., Potter D., Moore B., Diemand J., Madau P., Zemp M., Kuhlen M., Quilis V., 2009, MNRAS, 398, L21